THE WEATHER AND CIRCULATION OF APRIL 1953[1]—

A Cold, Stormy Month With a Low Index Circulation

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WEATHER HIGHLIGHTS

The weather in most of the United States during April 1953 was unusually cold and stormy, in striking contrast to the abnormally mild conditions which had prevailed during the preceding four months [1]. In some cities (Denver and Cheyenne) the monthly mean temperature during April (Chart I-A) was actually lower than during March; while at others (Charleston, Tallahassee, Fort Worth) it was only a few tenths of a degree higher. Chart I-B shows that temperatures averaged below normal in all parts of the country except for eastern and southern border areas. The largest departure from normal, −7° F., was reported at both Glasgow, Mont. and Valentine, Nebr., while departures of −6° F. were observed at many stations in the Northern Plains. In Montana, Billings had its coldest April on record and Havre experienced below-normal temperatures on all but 6 days of the month.

The cold weather first affected the West Coast and then gradually spread eastward. During the first week of April nighttime temperatures in the State of Washington dropped to the lowest levels since November 1952. On the 7th the Napa Valley of California experienced its first major freeze since 1936. Record-low temperatures were established on the 8th at Winnemucca, Nev. (9° F.) and on the 9th at Fresno, Calif. (32° F.). The coldest week of the month east of the Continental Divide was the period from April 14–20, when temperatures averaged as much as 15° F. below normal in parts of the Northern Plains. North Dakota reported the coldest mid-April week on record, with temperatures as low as 0° F. on the 17th.

April's cold weather was accompanied by unusually heavy snowfall (Charts IV and V). In parts of the Northern Rockies and Northern Plains some snow fell in every week of the month. During the week ending April 13, 24 inches accumulated on the eastern edge of Great Salt Lake in Utah, while 10 to 13 inches fell in northwestern Kansas. On the 14th Boston had its heaviest snowfall this late in the spring season during the last 35 years. During the week ending April 20 snow was observed in many parts of the country including such cities as Cleveland, St. Louis, and Indianapolis. As much as 12 inches fell in parts of North Dakota on the 23d and 24th, and up to 14 inches in the Black Hills of South Dakota on the last day of the month.

Other weather elements besides cold and snow made the headlines during April. High winds caused severe duststorms over the entire State of New Mexico on the 17th. Freezing rain occurred in the southern sections of Kansas, Illinois, and Indiana on the 18th. During the last week of the month torrential rains, high winds, and floods caused considerable damage in the lower Mississippi Valley, where a new 12-hour precipitation record of 8.75 inches for Vicksburg, Miss., was established on the 29th. Thunderstorms and hail occurred at intervals during the month throughout the South. Perhaps the most spectacular feature of the weather was the unusual frequency of tornadoes. The total number of tornadoes reported in the United States during the month was 65, almost three times the normal number for April. Over a dozen tornadoes occurred in the State of Alabama alone, most of them during the disastrous weekend of the 18th–19th.

LOW INDEX CIRCULATION

The cold, stormy weather in the United States was produced by a hemispheric circulation of the classic low index type. According to Willett [2]

> the low index circulation pattern, in contrast to the high index pattern, is characterized by:
>
> 1. A relatively strong poleward temperature gradient, at least between sea level and the 3-km. level.
>
> 2. Relatively weak zonal westerlies at sea level which increase to relatively strong aloft, with a tendency to be displaced equatorward, that is, an intensified and expanded circumpolar vortex in the upper troposphere.
>
> 3. Strong polar easterlies as a result of a relatively strong sea-level polar anticyclone, which in turn is produced primarily

[1] See charts I–XV following page 129 for analyzed climatological data for the month.

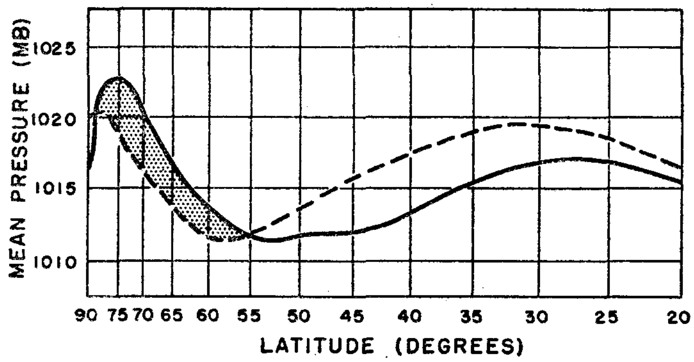


FIGURE 1.—Mean sea level pressure profile in the Western Hemisphere for March 30-April 28, 1953, with normal April profile dashed. Note positive anomaly of pressure north of 55° N. (shaded area) and negative anomaly to the south.

from a weakening of the subtropical high pressure belt.

4. In middle latitudes a relatively strong meridional circulation at sea level which tends to weaken with height as the zonal westerlies become stronger.

Most of this idealized description can be applied directly to the observed circulation of the Western Hemisphere during April 1953. At sea level the month was characterized by an excess of pressure in polar regions, north of 55° N., and a deficit of pressure to the south, at middle and low latitudes (fig. 1). As a result the polar easterly index was unusually high, while both the zonal westerlies and subtropical easterlies were abnormally weak (table 1). These low index features were particularly well marked

TABLE 1.—*Monthly mean indices in the Western Hemisphere during April 1953 (in meters per second)*

Index	Level	Observed	Normal	Departure from normal
Polar easterlies, 70°N.-55°N.	Sea level	3.0	1.6	+1.4
Zonal westerlies, 35°N.-55°N.	Sea level	1.2	2.5	−1.3
Subtropical easterlies, 35°N.-20°N.	Sea level	−0.1	1.8	−1.9
Polar westerlies, 55°N.-70°N.	700 mb	0.8	3.7	−2.9
Zonal westerlies, 35°N.-55°N.	700 mb	7.3	8.3	−1.0
Subtropical westerlies, 20°N-35°N.	700 mb	7.9	5.8	+2.1

in the Atlantic and North America, where monthly mean pressures in the polar anticyclones were as much as 12 mb. above normal, while the Azores-Bermuda high pressure belt was considerably weaker than normal (Chart XI and fig. 2). It is also noteworthy that the meridional circulation in middle latitudes was relatively strong, not only in the Atlantic and North America, but also throughout the Pacific.

At the 700-mb. level the April circulation also conformed closely to Willett's description of the low index state. Monthly mean heights were generally above normal in the polar region and at extremely low latitudes, while below-normal heights prevailed at most middle latitudes (fig. 3). As a result the subtropical westerlies were extremely strong, even stronger than the zonal westerlies, but the polar westerly index was well below normal (table 1). These features are well illustrated in the zonal wind speed profile for the Western Hemisphere (fig. 4) which shows that the westerlies were generally weaker than normal

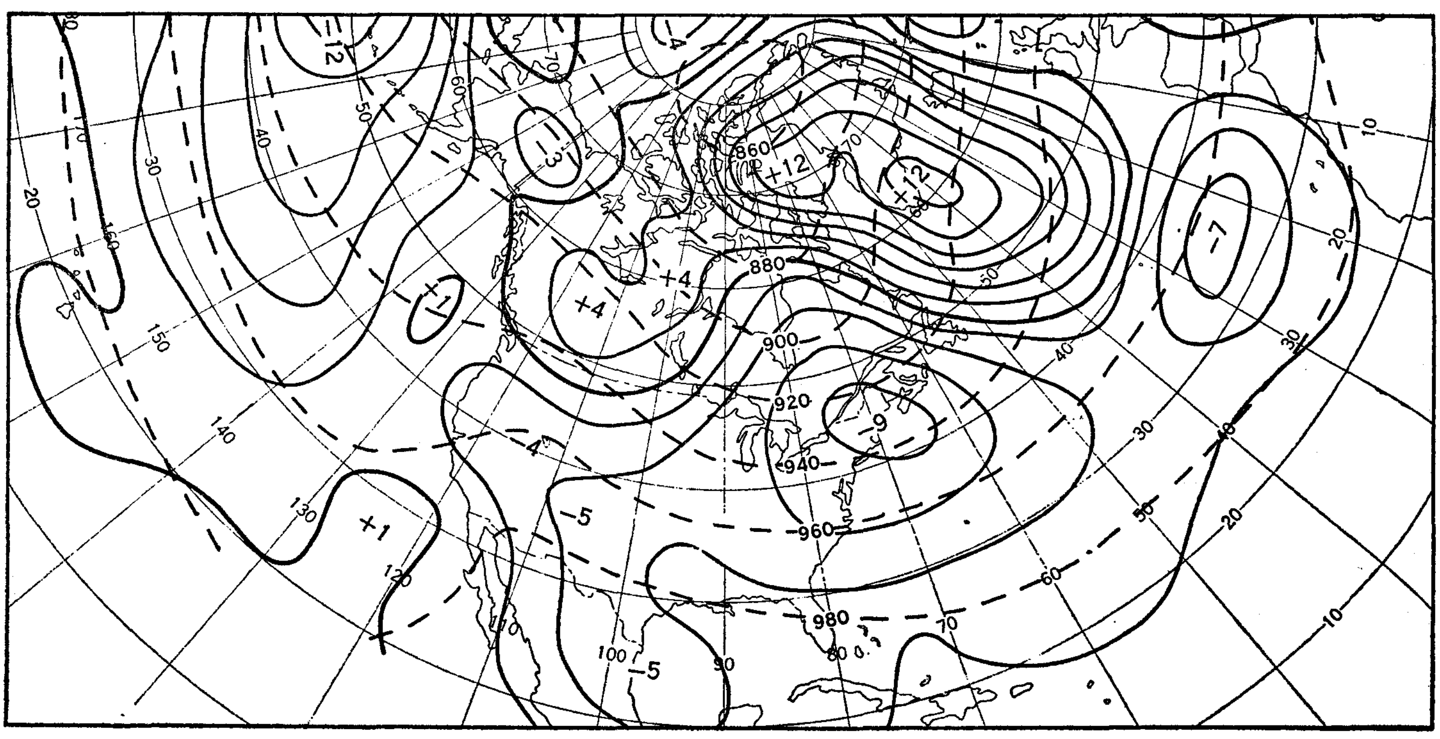


FIGURE 2.—Mean sea level pressure departure from normal for March 30-April 28, 1953 (at intervals of 2 mb.). Dashed lines indicate normal thickness (700 mb.-1,000 mb.) for April (in tens of feet). Note anomalous components of flow into the United States from cold source regions in Hudson Bay and eastern Pacific.

north of 43° N. but stronger than normal south of this latitude. Furthermore, the strongest westerlies, around 33° N., were about 5° south of their normal latitude and almost 2 meters per second stronger than normal. The regional distribution of total horizontal wind speed at 700 mb. is delineated in figure 5a. This map shows that the axis of strongest wind speed was located around 40° N. in the eastern Pacific and 5° to 10° farther south in the Atlantic. In North America this "jet stream" was split into two parts, with the principal branch passing through Mexico and Texas and a weaker branch traversing the northwestern United States. Figure 5b simplifies this picture somewhat since it shows that wind speeds were generally weaker than normal in Canada but stronger than normal in the United States, so that the westerlies showed a distinct tendency "to be displaced equatorward." Thus the April low index circulation was clearly characterized by an "intensified and expanded circumpolar vortex" at least at the 700-mb. level.

The monthly mean 200-mb. chart (fig. 6) is also indicative of the low index state since it shows a pronounced jet stream at relatively low latitudes (25°–40° N.) girdling

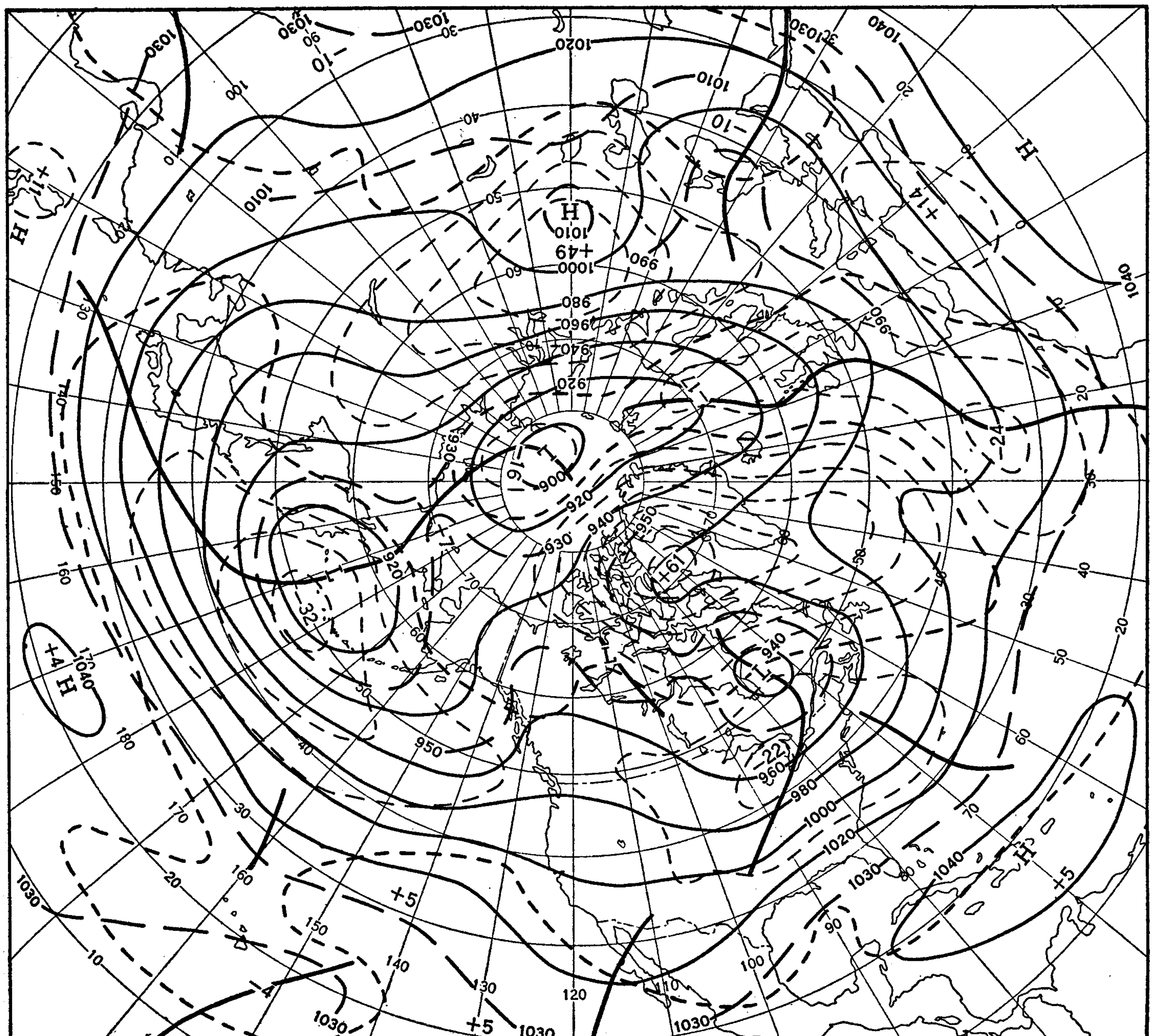


FIGURE 3.—Mean 700-mb. height contours and departures from normal (both in tens of feet) for March 30–April 28, 1953. Features of interest include strong blocking ridge over Baffin Bay, subpolar Low displaced south to James Bay, and negative height anomalies throughout United States.

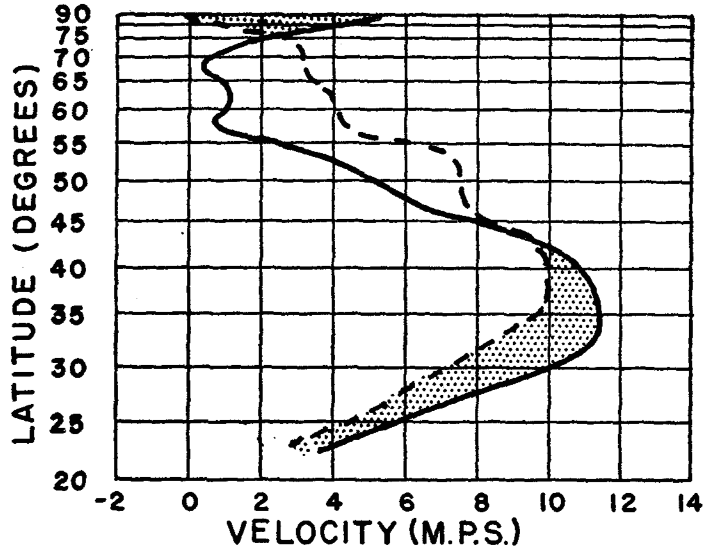


FIGURE 4.—Mean 700-mb. zonal wind speed profile in the Western Hemisphere for March 30-April 28, 1953, with normal April profile dashed and area of positive anomaly shaded. The west wind maximum at 33° N. was stronger and farther south than normal.

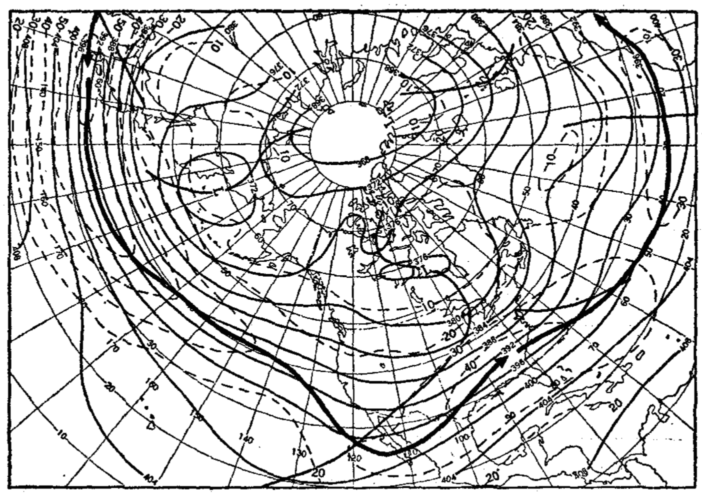


FIGURE 6.—Mean 200-mb. contours (in hundreds of feet) and isotachs (in meters per second) for March 30-April 28, 1953. Solid arrows indicate the average position of the jet stream, which was located directly over the 700-mb. jet stream in the Pacific, but a few degrees farther south in other areas.

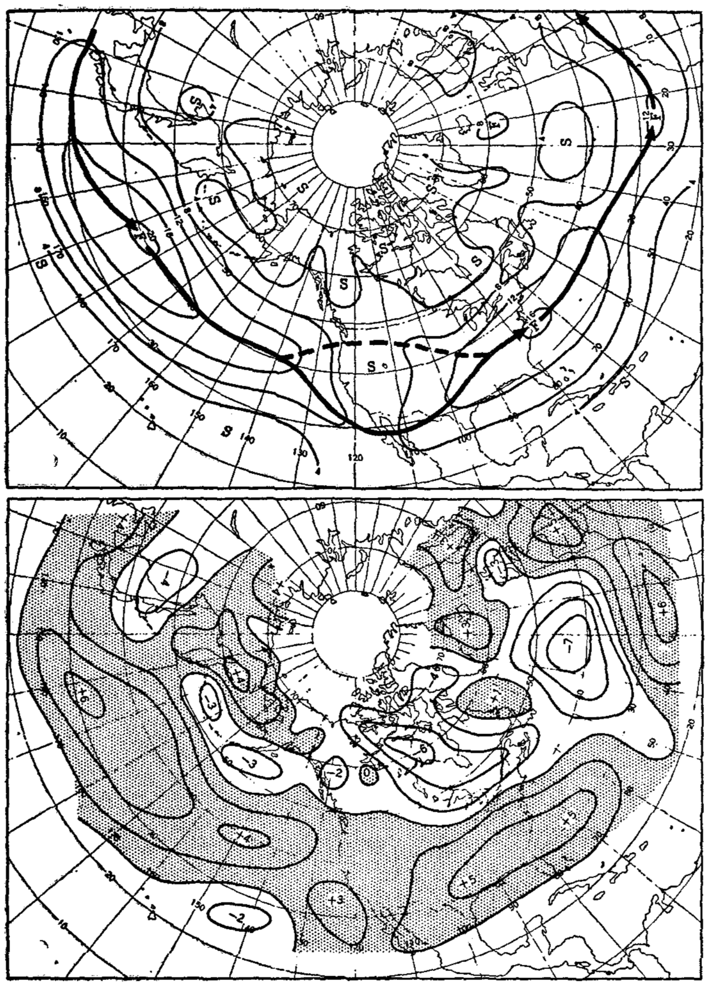


FIGURE 5.—Mean 700-mb. isotachs (*a*) and departure from normal wind speed (*b*) (both in meters per second) for March 30-April 28, 1953. Solid arrows indicate the average position of the jet stream, which was south of its normal location in nearly all sectors. Dashed line delineates secondary zone of maximum wind speed across northwestern United States.

three-fourths of the Northern Hemisphere. It must be admitted, however, that the 200-mb. surface is probably above the "upper troposphere" mentioned by Willett, particularly at higher latitudes. This may explain the disappearance at 200 mb. of the secondary jet stream noted at 700 mb. in the northwestern United States (fig. 5a). This jet stream may correspond to what Palmén [3] calls the "polar front jet", while the principal jet stream in figure 6 may be the "subtropical jet" which tends to lie almost vertically above the subtropical high pressure belt (compare fig. 6 with Chart XI).

The only part of Willett's description which was not verified by the April data is item 1 calling for a "relatively strong poleward temperature gradient" between sea level and 3 km. In order to check this point a profile was computed showing the thickness of the layer between 1,000 and 700 mb. averaged over the Western Hemisphere. This profile has not been reproduced because it showed thickness very close to normal at every latitude. The regional distribution of the thickness departure from normal, illustrated in figure 7, explains the reason for this near normal profile. This chart shows that the poleward temperature gradient at middle latitudes was indeed stronger than normal in the eastern Pacific and western North America, but it was definitely weaker than normal in the western Atlantic and eastern North America. However, it was precisely the Atlantic sector which had the lowest index conditions, whereas the Pacific circulation was more of the high index type. For this reason, and because of the well-known fact that blocking Highs are usually warm (e. g., the large High over Greenland and northeast Canada this month) while Lows at low latitudes are frequently cold, the first item of Willett's description does not appear to be typical of the low index state, at least not in the Western Hemisphere.

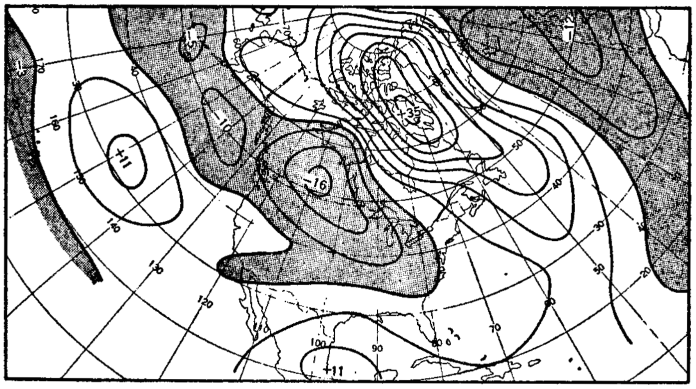


FIGURE 7.—Mean departure from normal of thickness (700 mb.-1,000 mb.) for March 30-April 28, 1953, analyzed for intervals of 50 feet with centers labeled in tens of feet. Below normal thicknesses (shaded) covered most of the United States, with center of −160 ft. corresponding to mean virtual temperature about 5° C. below normal. Note warmth of blocking High over northeast Canada with center almost 12° C. (350 ft.) above normal.

INTERRELATION BETWEEN WEATHER AND CIRCULATION

The low index circulation was reflected in the southward displacement and meridional nature of the tracks of anticyclones (Chart IX and fig. 8a) and cyclones (Chart X and fig. 8b). The principal anticyclone track in the United States was extremely well defined. Migratory Highs entering the northwestern United States from the eastern Pacific and northwest Canada plunged far southward through the Great Plains and Gulf States before moving eastward at unusually low latitudes (30°–35° N.) in the Atlantic. Cyclone tracks were not as concentrated but they showed a definite tendency to be located south of normal in all sectors. Considerable stalling, looping, and meridional motion were also evident. Storms which entered the United States from the Pacific traversed the northwestern part of the country, parallel to the secondary jet stream at 700 mb. To the south, where the primary jet was located, cyclogenesis and "secondary" formations were frequent, particularly near Nevada, Colorado, and the Middle Atlantic Coast.

The unusually low latitude of the jet stream and associated anticyclone and cyclone tracks enabled cold polar air to penetrate most of the United States. This cold air came from two principal sources, Hudson Bay and the eastern Pacific, and followed approximately the same trajectory as the principal anticyclone track illustrated in figure 8a.[2] In April these two regions are normally among the coldest parts of North America and vicinity; this year the anomalous components of flow, both at sea level and aloft, came directly from these cold sources into the United States. In order to illustrate this, the normal thickness lines for April (1,000–700 mb.) have been superimposed on the departure from normal of the monthly mean sea level pressure (fig. 2). The advection of cold

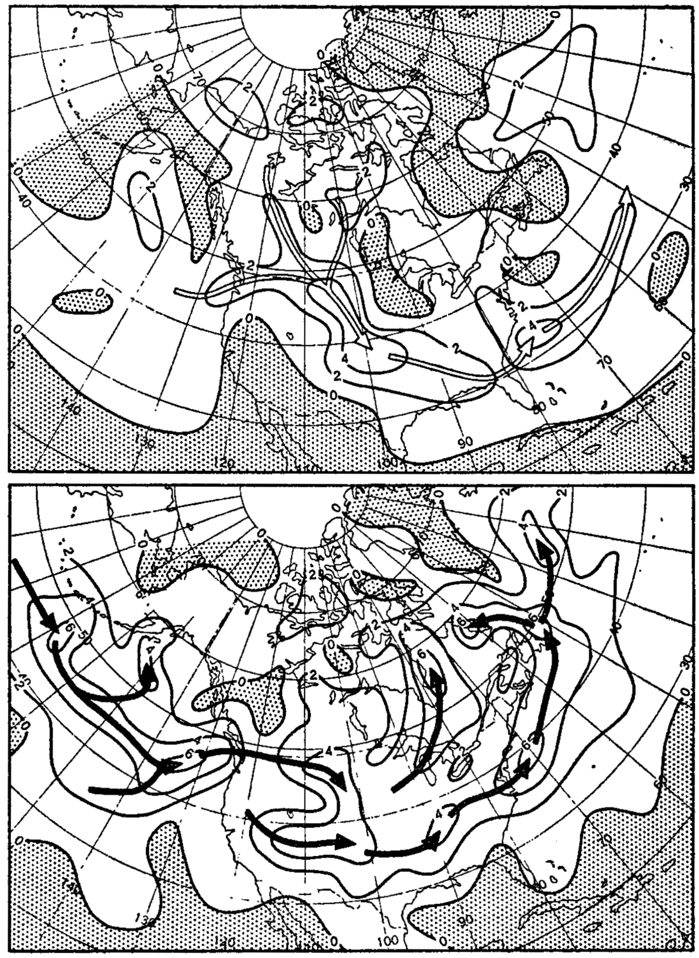


FIGURE 8.—Frequency of anticyclone passages (a) and cyclone passages (b) (within 5° squares at 45° N.) during April 1953. Well defined anticyclone tracks are indicated by open arrows and cyclone tracks by solid arrows. Effect of the low index is apparent in meridional components and southward displacement of tracks. (All data derived from Charts IX and X.)

"climate" from the Hudson Bay and eastern Pacific sources is evident in this figure. The cooling effect of stronger than normal west winds in the western part of the country this month contrasts sharply with its warming effect during the past winter [1]. A ready explanation is provided by the normal thickness lines, which show that air over the Pacific ocean is warmer than air over the United States in winter but colder in spring and summer [4].

After entering the United States the cold air was prevented from rapid warming by excessive cloudiness (Charts VI and VII), abundant storminess (Chart X), and cyclonic circulation with below normal heights at 700 mb. (fig. 3). The only places sheltered from the recurrent cold outbreaks were the North and Middle Atlantic Coasts, the Rio Grande Valley, and parts of Florida and the Gulf Coast. In those regions monthly mean temperatures averaged a few degrees above normal under the influence of some southerly components of flow east of the primary trough at 700 mb.

Total precipitation during the month (Chart II) generally exceeded normal amounts (Chart III) as the prin-

[2] For an example of a severe cold outbreak associated with a polar High originating just west of Hudson Bay, see adjoining article by Malkin and Holzworth.

cipal storm tracks were displaced from Canada into the United States by the low index circulation. Four principal types of heavy precipitation can be delineated. Pacific moisture carried by stronger than normal westerlies was responsible for above-normal amounts west of the Continental Divide. In California the drought of the previous two months was broken as statewide precipitation averaged 162 percent of normal. Heavy precipitation in the North and Middle Atlantic States was associated chiefly with the unusual frequency of coastal storms. Excessive storminess in this area is indicated by the fact that monthly mean sea level pressure was as much as 8 mb. below normal throughout the Northeast, while the "Icelandic" Low was displaced to Nova Scotia (Chart XI).

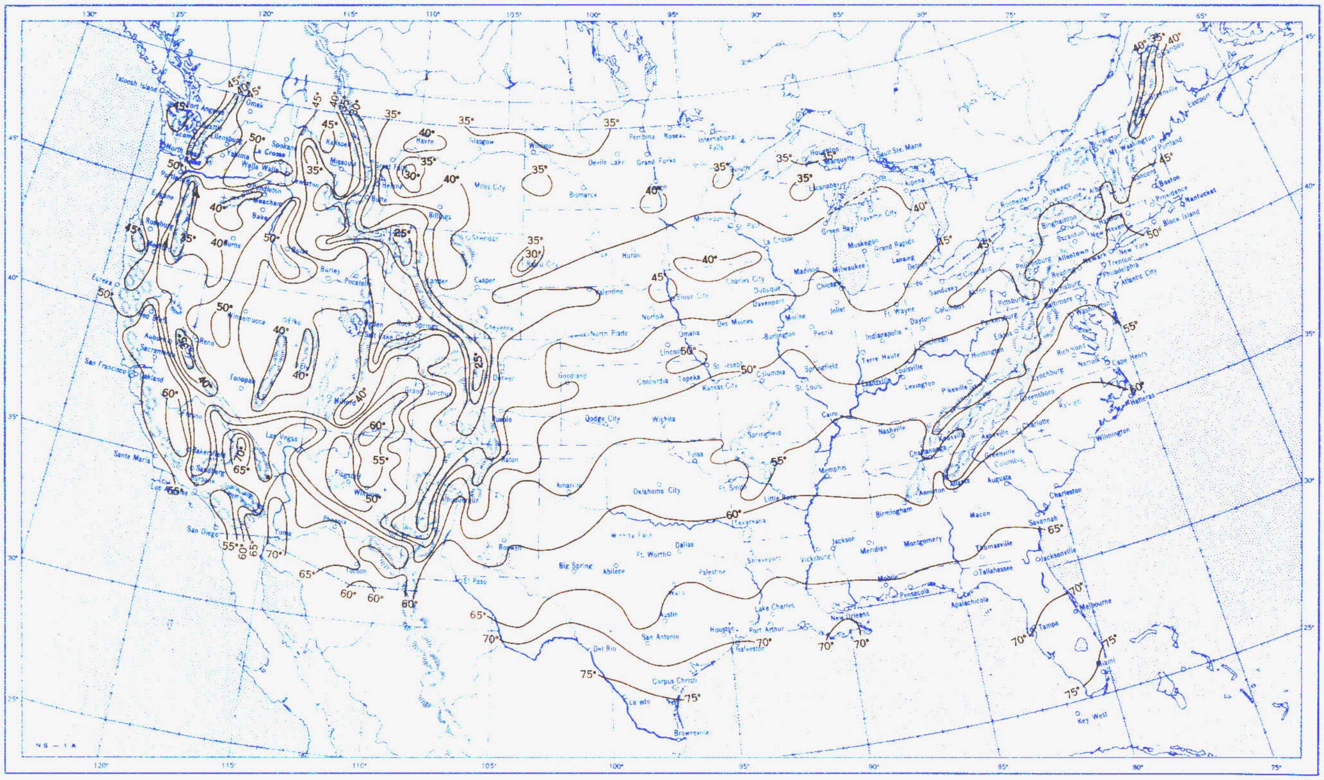
In the central part of the country there were two sharply contrasting bands of excess precipitation. Heavy rains and snow in the Northern Plains, Upper Mississippi Valley, and western Lakes Region were produced by overrunning of cold polar continental air by moist Pacific and Gulf air. Much of this precipitation fell with northeasterly winds at the surface as cyclones passed to the south, as may be inferred from the prevalence of anomalous wind components from the east on the monthly mean charts at sea level and 700 mb. in this area. Statewide precipitation in North Dakota averaged 182 percent of normal. Gulf moisture produced excessive rains in most of the south-central and southeastern parts of the Nation. Most of this rain was of the showery type, caused by forced lifting at cold fronts and squall lines, as cold Pacific air, carried by unusually strong westerlies, replaced warm maritime tropical air in the area. The resulting instability was sufficiently great to produce numerous thunderstorms and tornadoes throughout the South.

In between these two bands of heavy precipitation a narrow zone of subnormal rainfall extended from the southern and central Plains through the Ohio Valley to the eastern Lakes Region and the Carolinas. Most of this zone was located between the two principal storm tracks in the United States (fig. 8b) and between the two branches of the jet stream at 700 mb. (fig. 5a). It is noteworthy that a close relation of the type noted by Starrett [5] seemed to exist between precipitation and the jet stream throughout the West. Less than one-forth of normal precipitation fell during April in parts of Kansas. By the close of the month a moisture deficiency of drought proportions was reported from this State as well as from parts of Nebraska, Oklahoma, Texas, New Mexico, and Colorado. Light rainfall in this area was also associated with downslope motion in stronger than normal northwesterly flow to the rear of the 700-mb. trough.

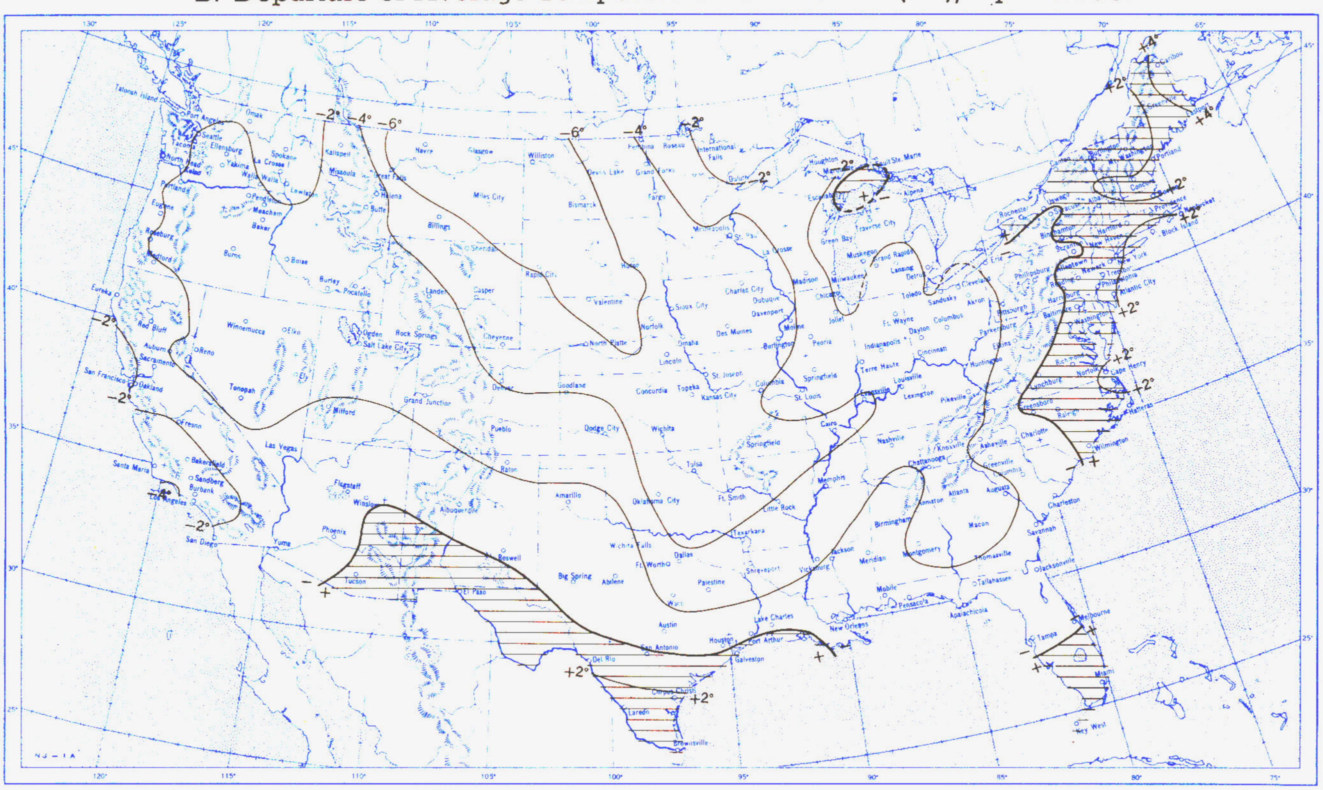
REFERENCES

1. W. H. Klein, "The Weather and Circulation of March 1953—Including a Review of This Year's Mild Winter", *Monthly Weather Review*, vol. 81, No. 3, March 1953, pp. 77–81.
2. H. C. Willett, "Patterns of World Weather Changes," *Transactions of the American Geophysical Union*, vol. 29, No. 6, December 1948, pp. 803–809.
3. E. Palmén, "The Role of Atmospheric Disturbances in the General Circulation," *Quarterly Journal of the Royal Meteorological Society*, vol. 77, No. 333, July 1951, pp. 337–354.
4. U. S. Weather Bureau, "Normal Weather Charts for the Northern Hemisphere," *Technical Paper No. 21*, Washington, D. C., October 1952, 74 pp.
5. L. S. Starrett, "The Relation of Precipitation Patterns in North America to Certain Types of Jet Streams at the 300-Millibar Level," *Journal of Meteorology*, vol. 6, No. 5, October 1949, pp. 347–352.

Chart I. A. Average Temperature (°F.) at Surface, April 1953.



B. Departure of Average Temperature from Normal (°F.), April 1953.

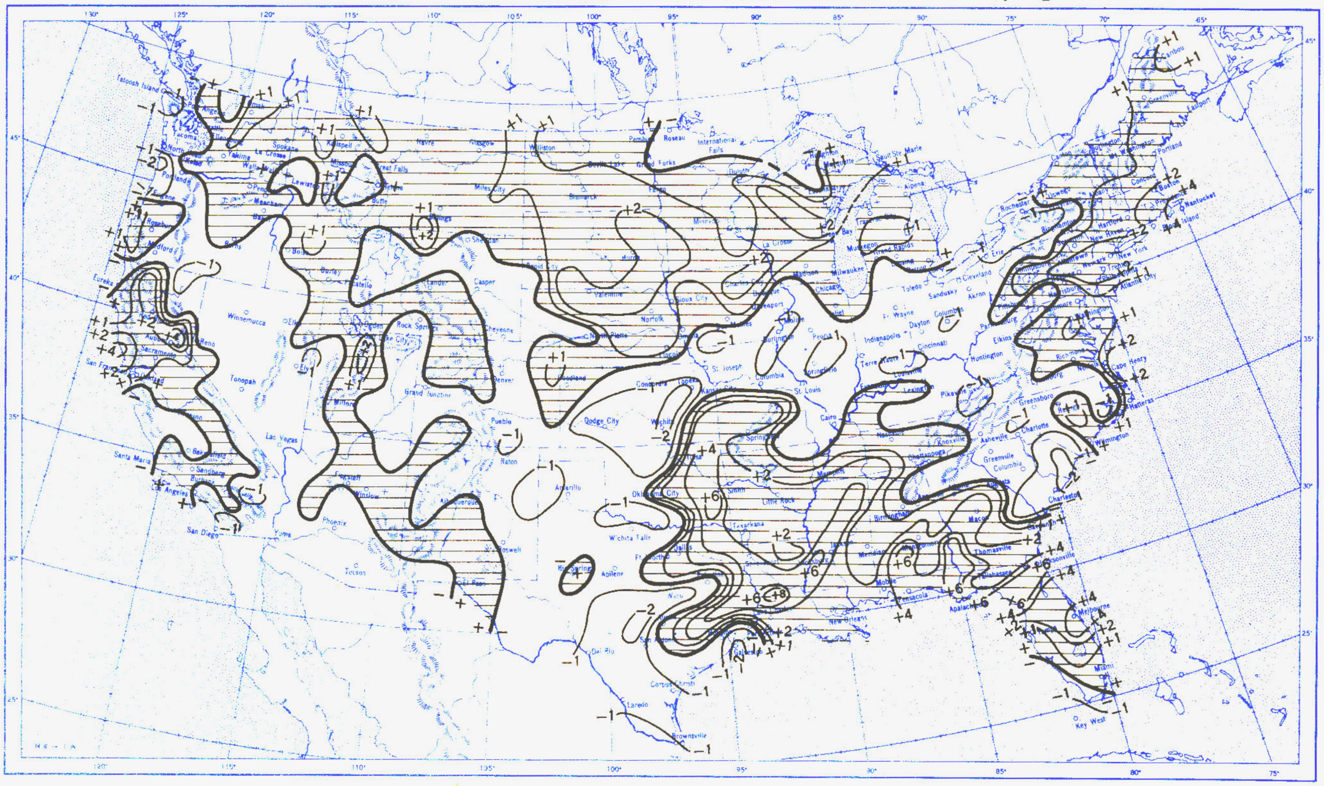


A. Based on reports from 800 Weather Bureau and cooperative stations. The monthly average is half the sum of the monthly average maximum and monthly average minimum, which are the average of the daily maxima and daily minima, respectively.
B. Normal average monthly temperatures are computed for Weather Bureau stations having at least 10 years of record.

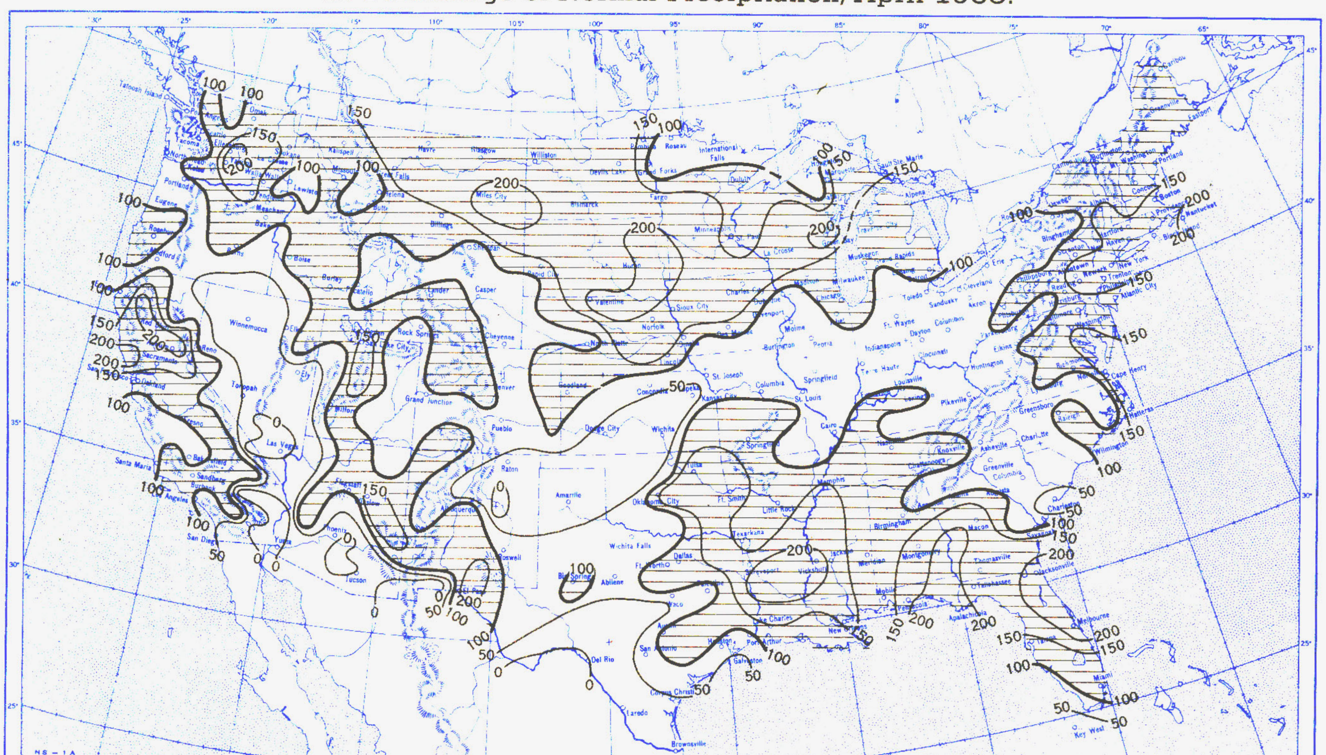
Chart II. Total Precipitation (Inches), April 1953.

Based on daily precipitation records at 800 Weather Bureau and cooperative stations.

Chart III. A. Departure of Precipitation from Normal (Inches), April 1953.

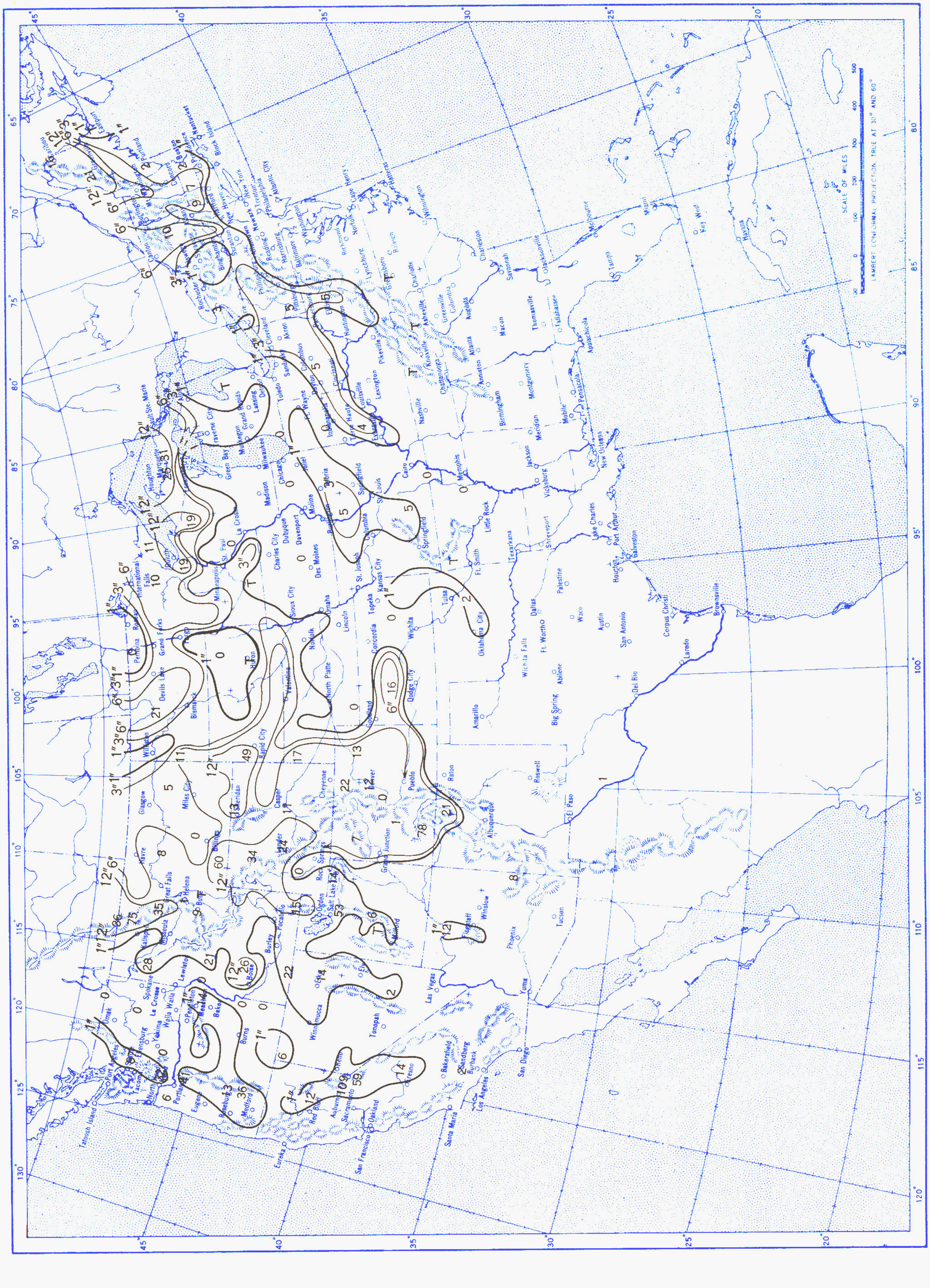


B. Percentage of Normal Precipitation, April 1953.



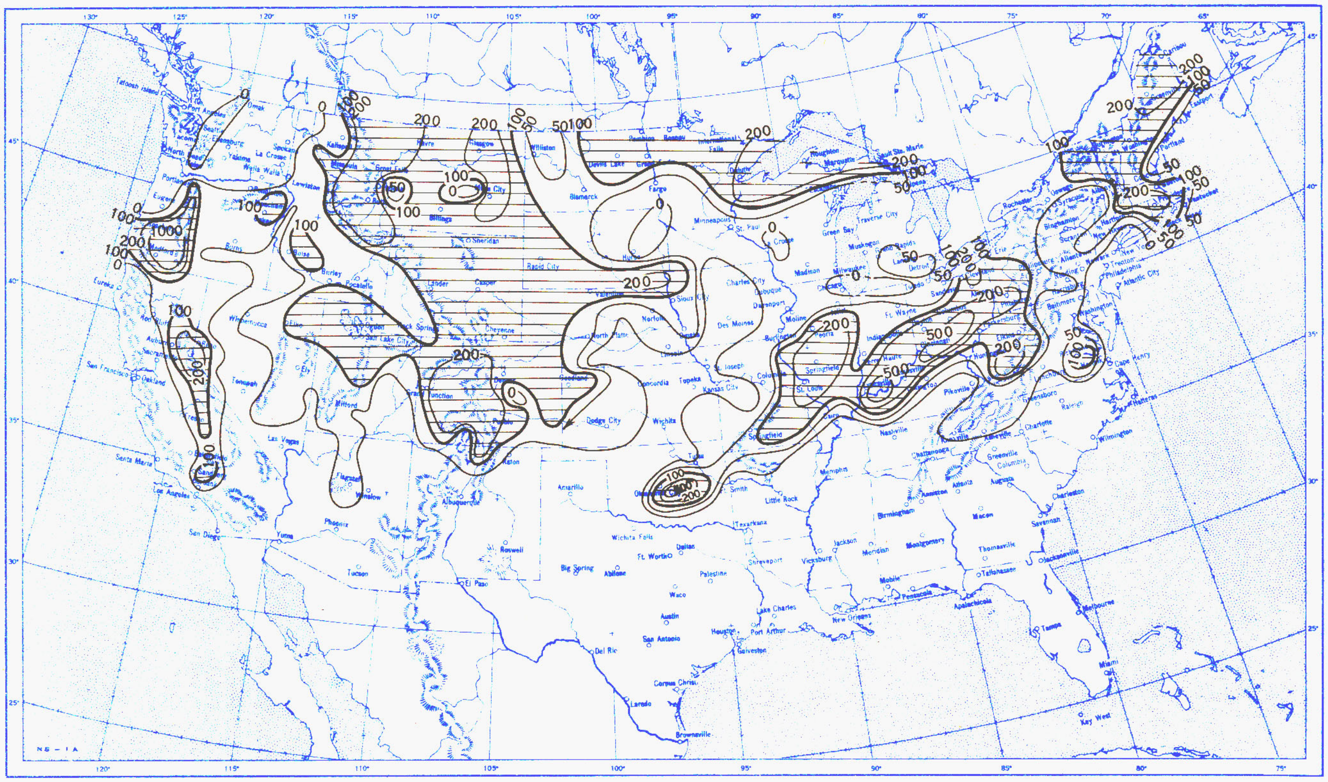
Normal monthly precipitation amounts are computed for stations having at least 10 years of record.

Chart IV. Total Snowfall (Inches), April 1953.

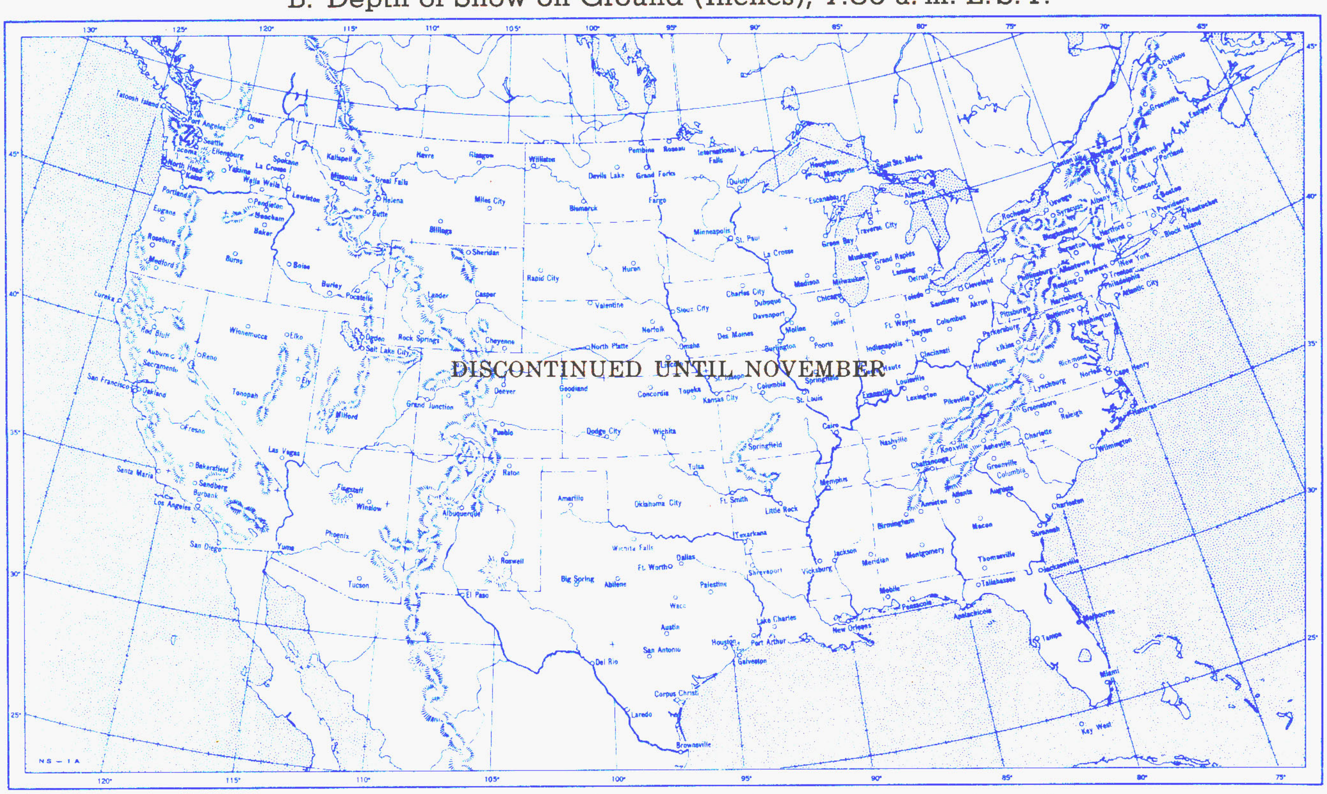


This is the total of unmelted snowfall recorded during the month at Weather Bureau and cooperative stations. This chart and Chart V are published only for the months of November through April although of course there is some snow at higher elevations, particularly in the far West, earlier and later in the year.

Chart V. A. Percentage of Normal Snowfall, April 1953.

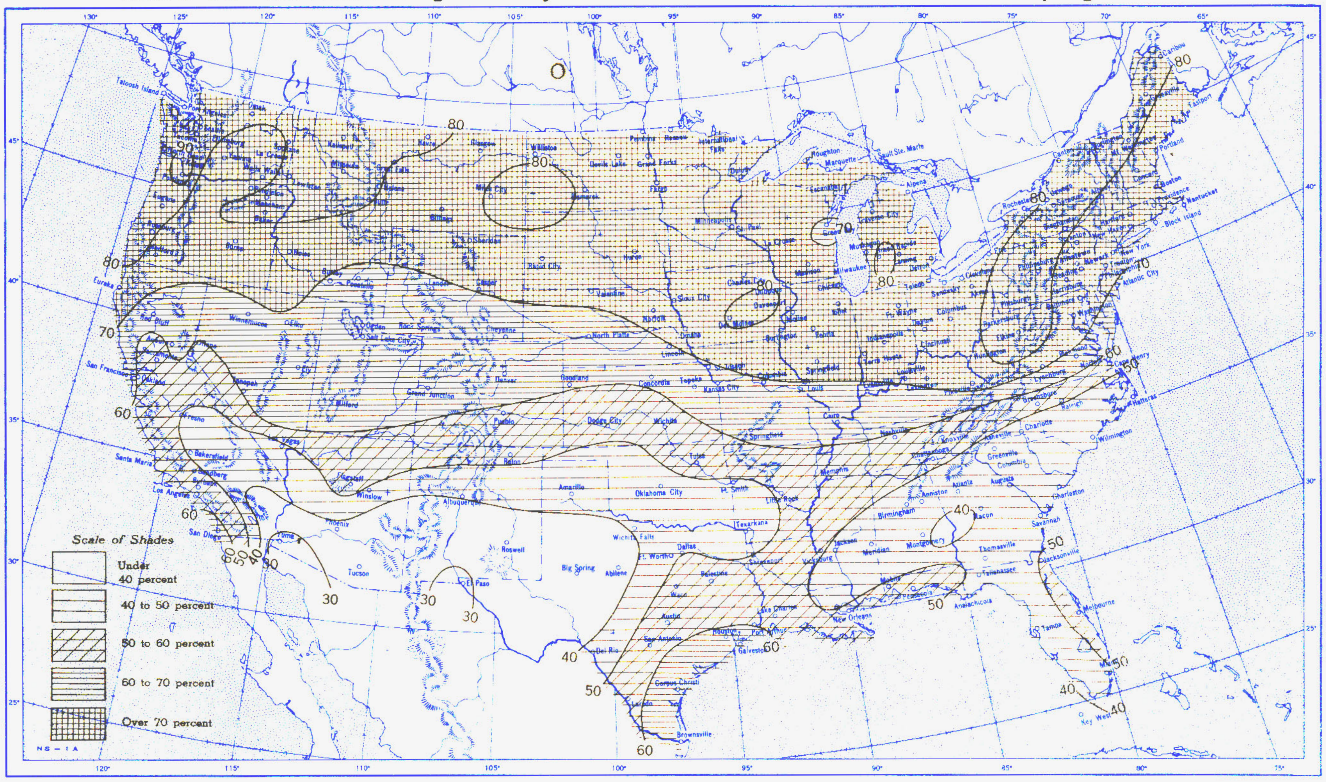


B. Depth of Snow on Ground (Inches), 7:30 a. m. E. S. T.

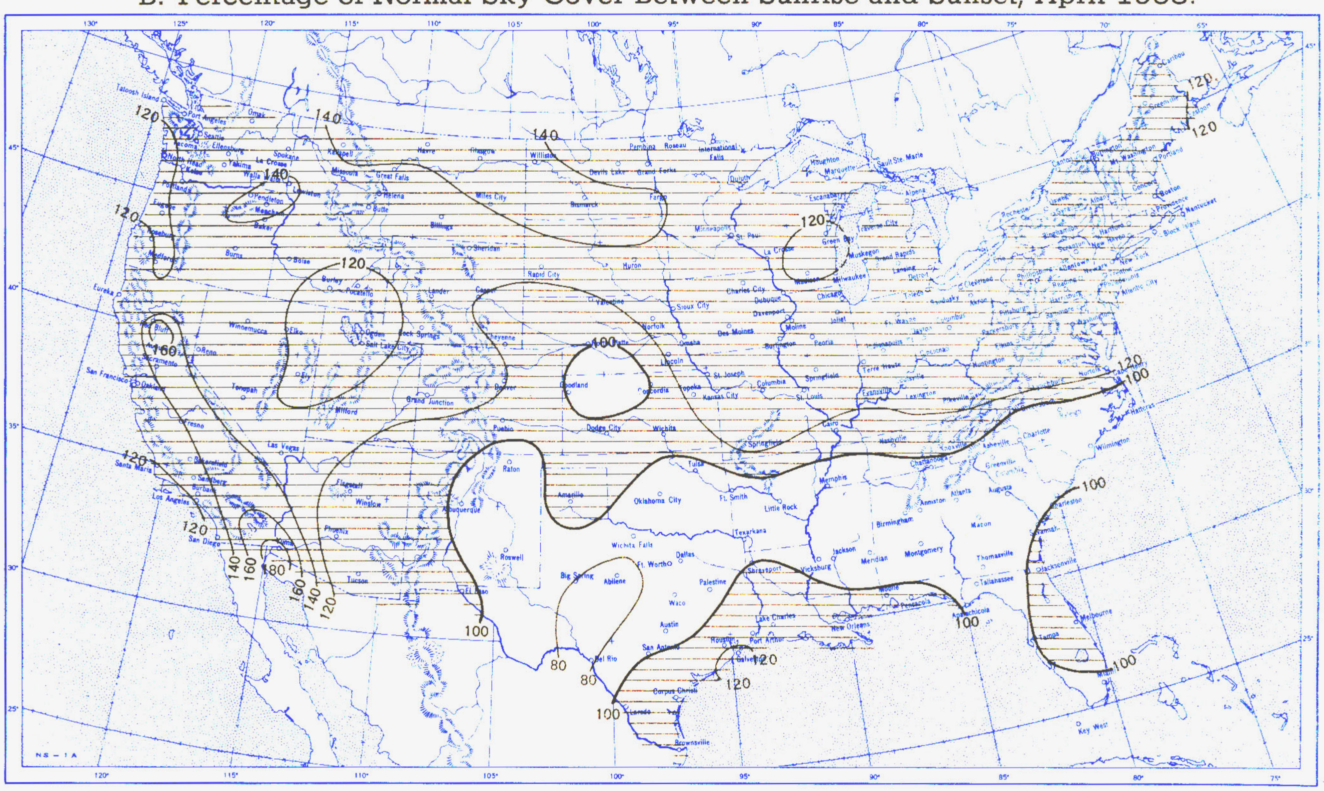


A. Amount of normal monthly snowfall is computed for Weather Bureau stations having at least 10 years of record.
B. Shows depth currently on ground at 7:30 a. m. E. S. T., of the Tuesday nearest the end of the month. It is based on reports from Weather Bureau and cooperative stations. Dashed line shows greatest southern extent of snowcover during month.

Chart VI. A. Percentage of Sky Cover Between Sunrise and Sunset, April 1953.

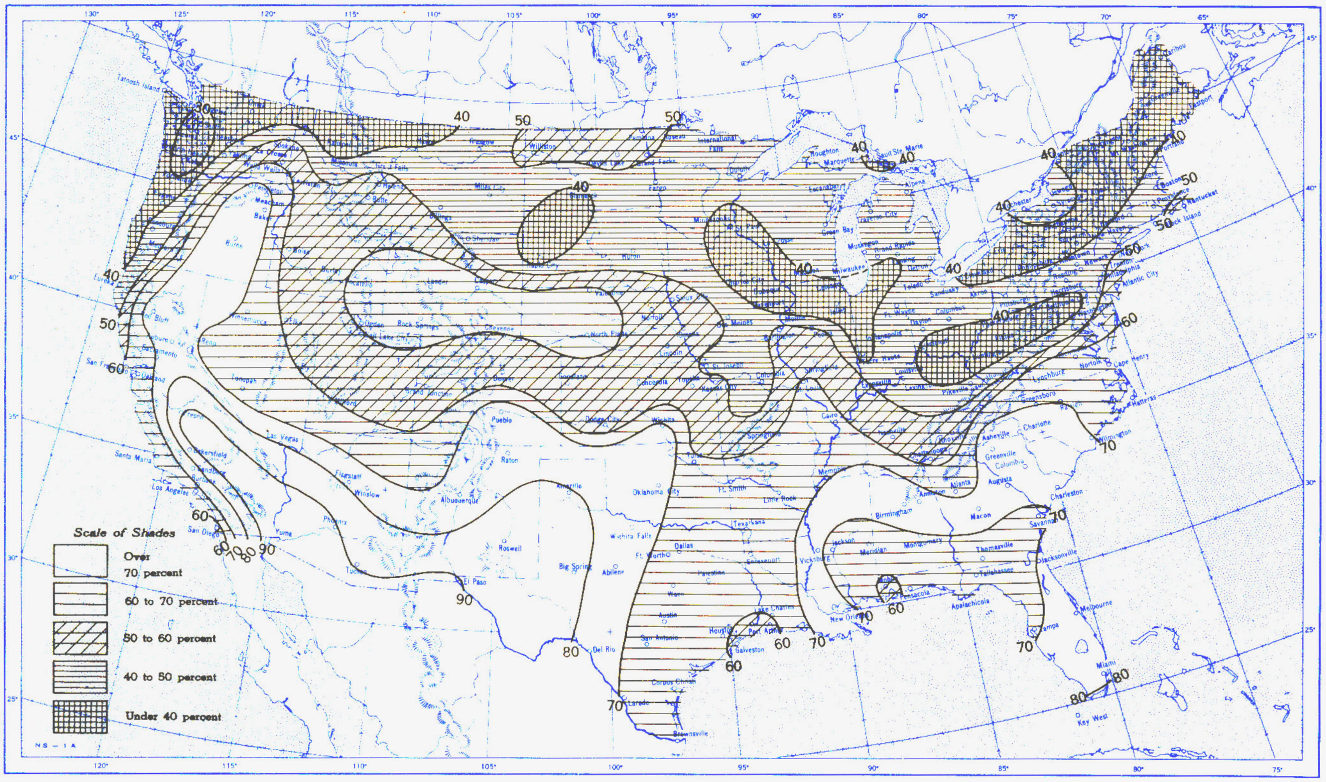


B. Percentage of Normal Sky Cover Between Sunrise and Sunset, April 1953.

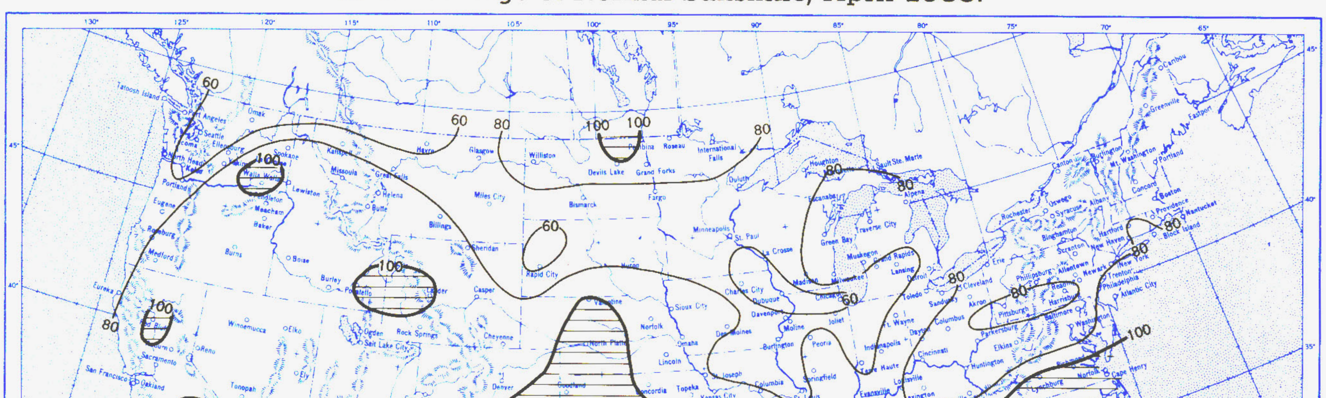


A. In addition to cloudiness, sky cover includes obscuration of the sky by fog, smoke, snow, etc. Chart based on visual observations made hourly at Weather Bureau stations and averaged over the month. B. Computations of normal amount of sky cover are made for stations having at least 10 years of record.

Chart VII. A. Percentage of Possible Sunshine, April 1953.



B. Percentage of Normal Sunshine, April 1953.



A. Computed from total number of hours of observed sunshine in relation to total number of possible hours of sunshine during month. B. Normals are computed for stations having at least 10 years of record.

Chart VIII. Average Daily Values of Solar Radiation, Direct + Diffuse, April 1953. Inset: Percentage of Normal Average Daily Solar Radiation, April 1953.

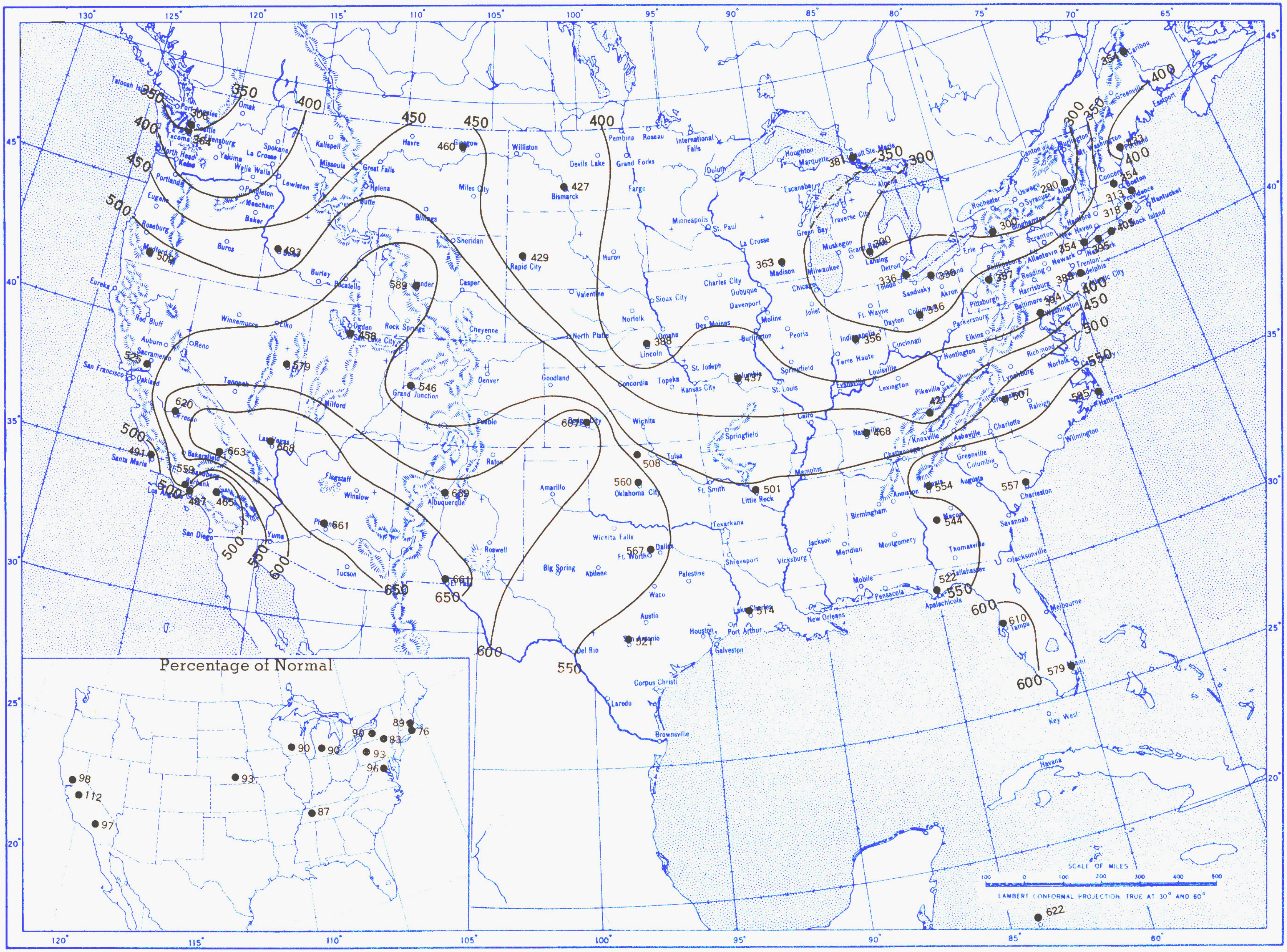
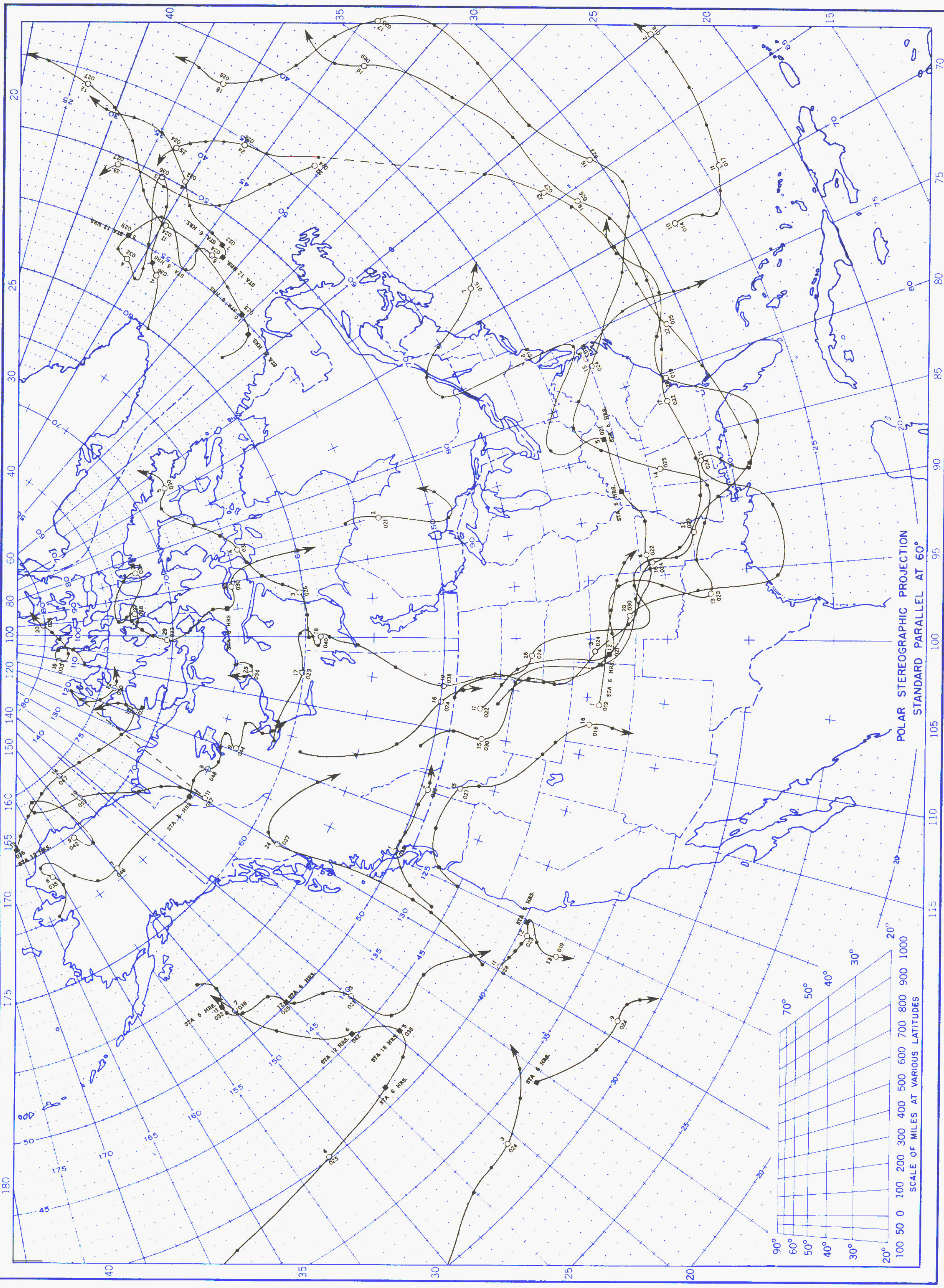


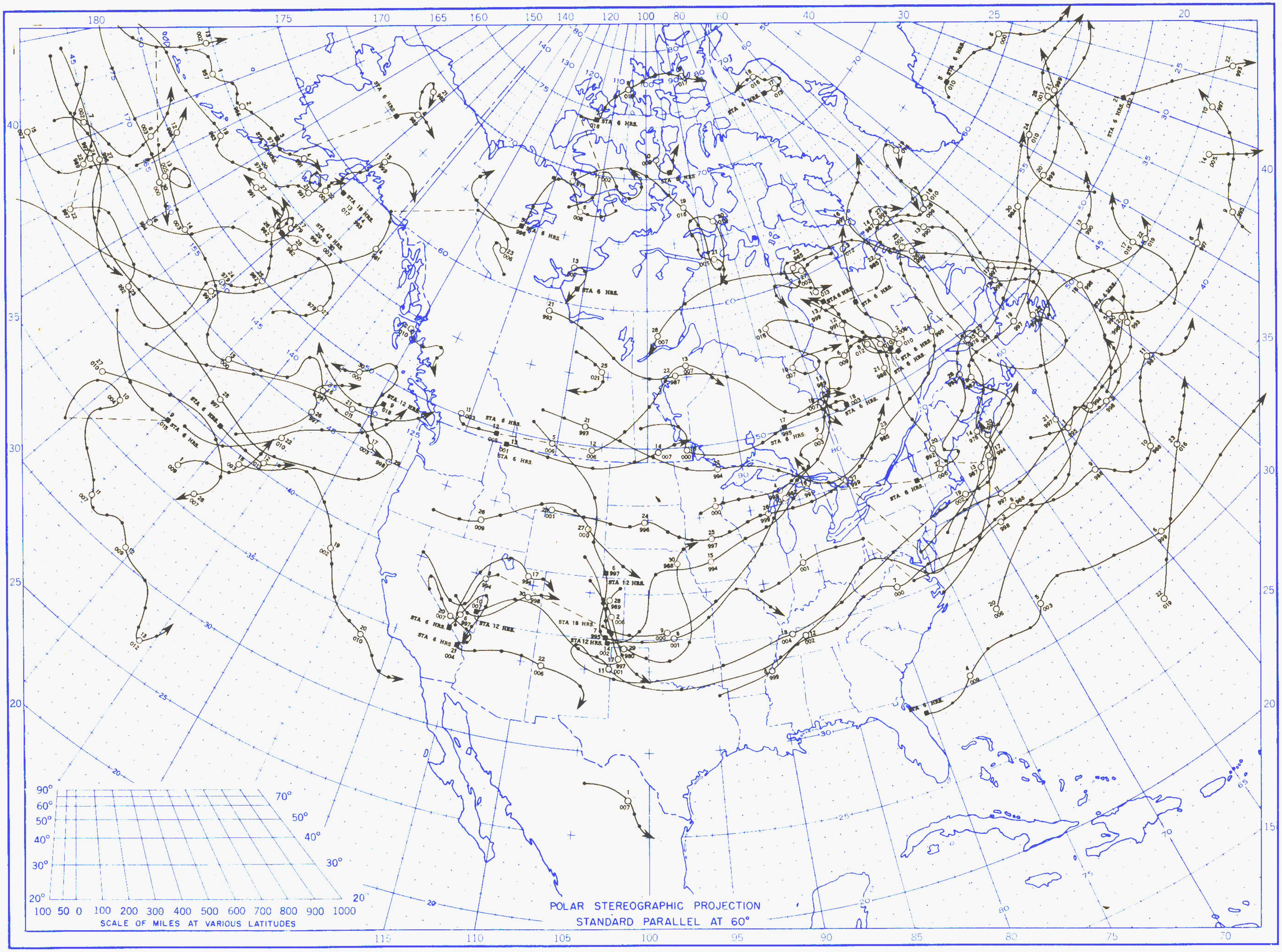
Chart shows mean daily solar radiation, direct + diffuse, received on a horizontal surface in langleys (1 langley = 1 gm. cal. cm. $^{-2}$). Basic data for isolines are shown on chart. Further estimates are obtained from supplementary data for which limits of accuracy are wider than for those data shown. Normals are computed for stations having at least 9 years of record.

Chart IX. Tracks of Centers of Anticyclones at Sea Level, April 1953.



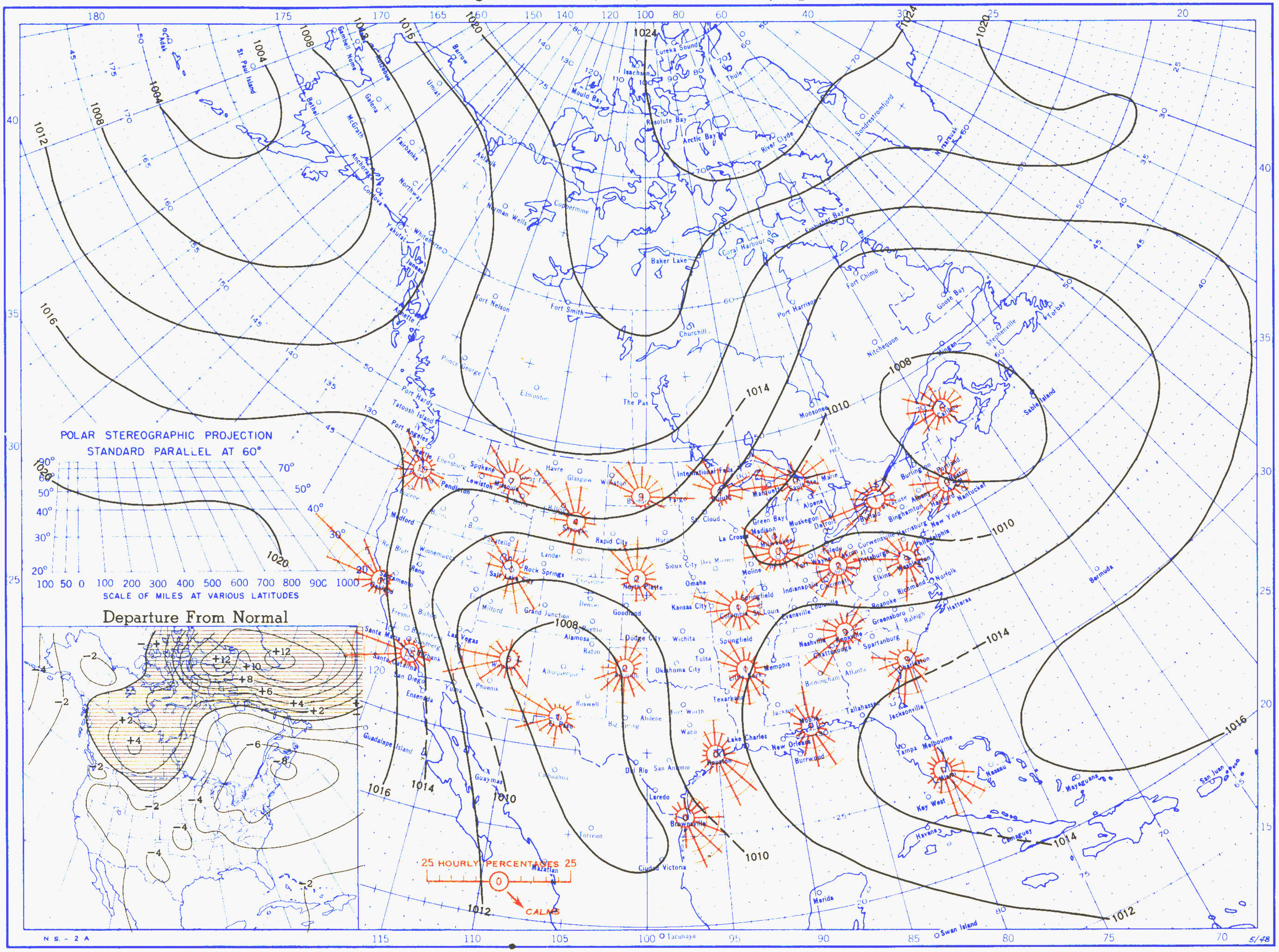
Circle indicates position of center at 7:30 a. m. E. S. T. Figure above circle indicates date, figure below, pressure to nearest millibar. Dots indicate intervening 6-hourly positions. Squares indicate position of stationary center for period shown. Dashed line in track indicates reformation at new position. Only those centers which could be identified for 24 hours or more are included.

Chart X. Tracks of Centers of Cyclones at Sea Level, April 1953.



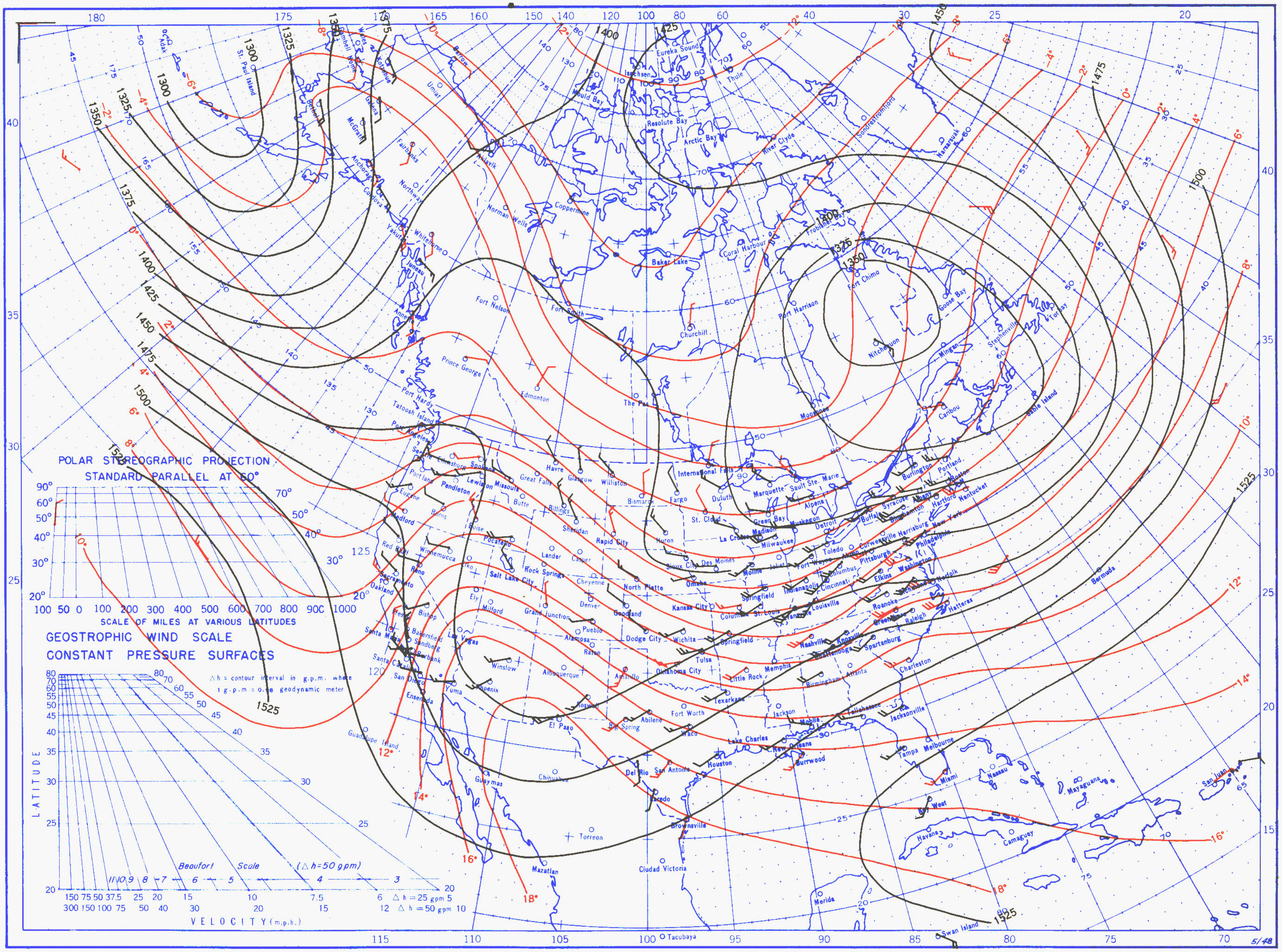
Circle indicates position of center at 7:30 a. m. E. S. T. See Chart IX for explanation of symbols.

Chart XI. Average Sea Level Pressure (mb.) and Surface Windroses, April 1953. Inset: Departure of Average Pressure (mb.) from Normal, April 1953.



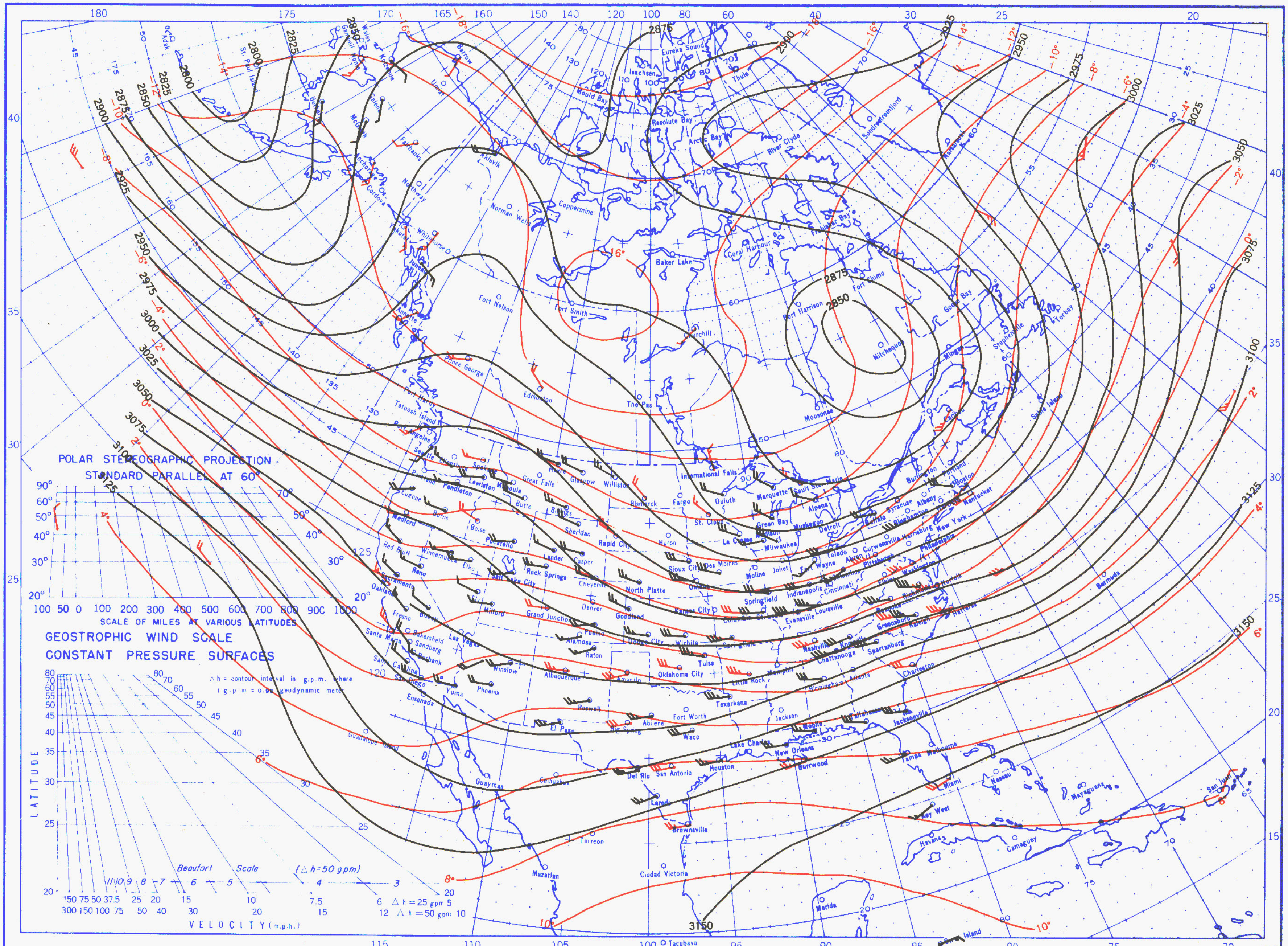
Average sea level pressures are obtained from the averages of the 7:30 a. m. and 7:30 p. m. E. S. T. readings. Windroses show percentage of time wind blew from 16 compass points or was calm during the month. Pressure normals are computed for stations having at least 10 years of record and for 10° intersections in a diamond grid based on readings from the Historical Weather Maps (1899-1939) for the 20 years of most complete data coverage prior to 1940.

Chart XII. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 850-mb. Pressure Surface, Average Temperature in °C. at 850 mb., and Resultant Winds at 1500 Meters (m.s.l.), April 1953.



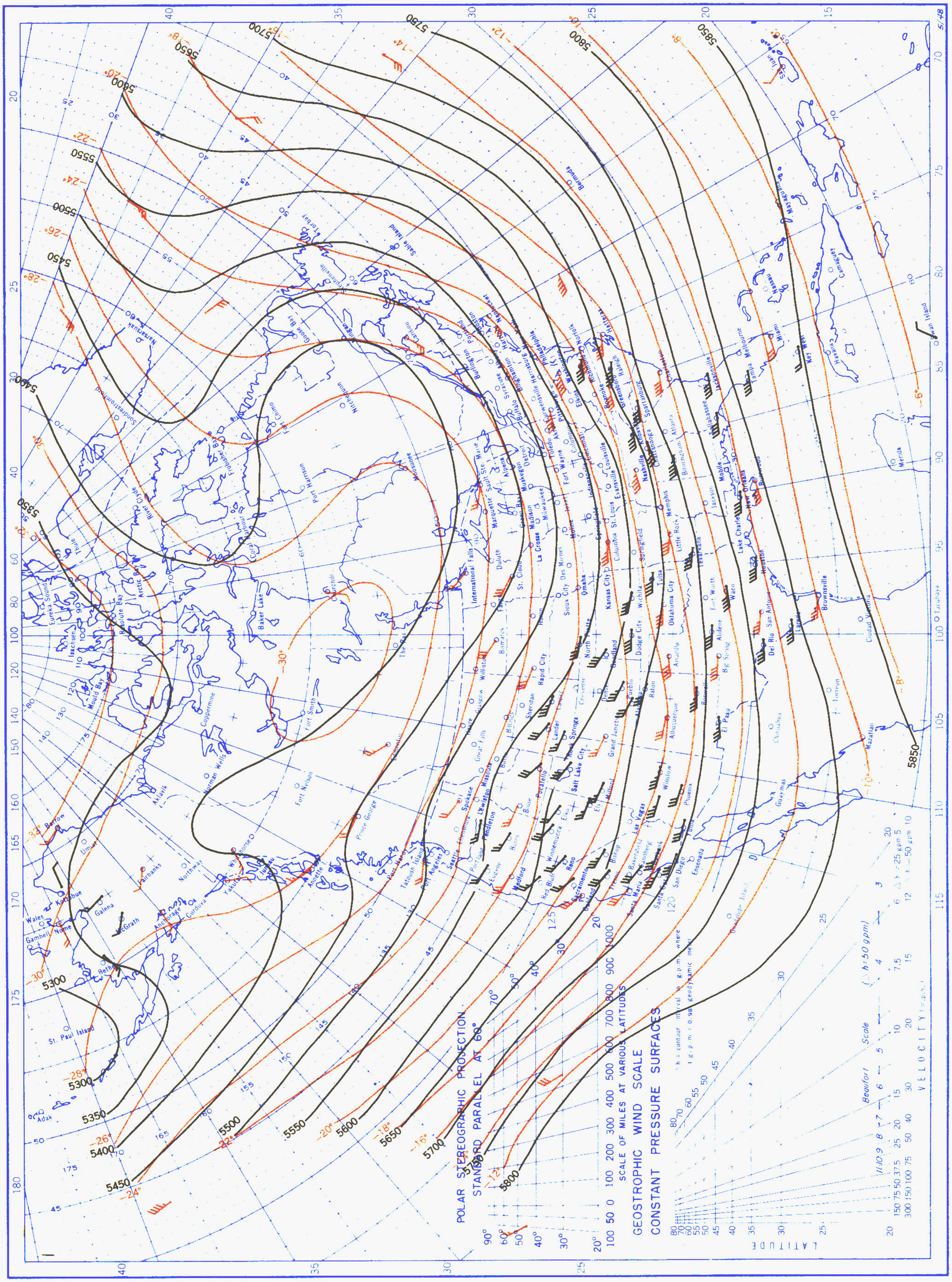
Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins taken at 0300 G. M. T.

Chart XIII. Average Dynamic Height in Geopotential Meters (1 g.p.m.. = 0.98 dynamic meters) of the 700-mb. Pressure Surface, Average Temperature in °C. at 700 mb., and Resultant Winds at 3000 Meters (m.s.l.), April 1953.



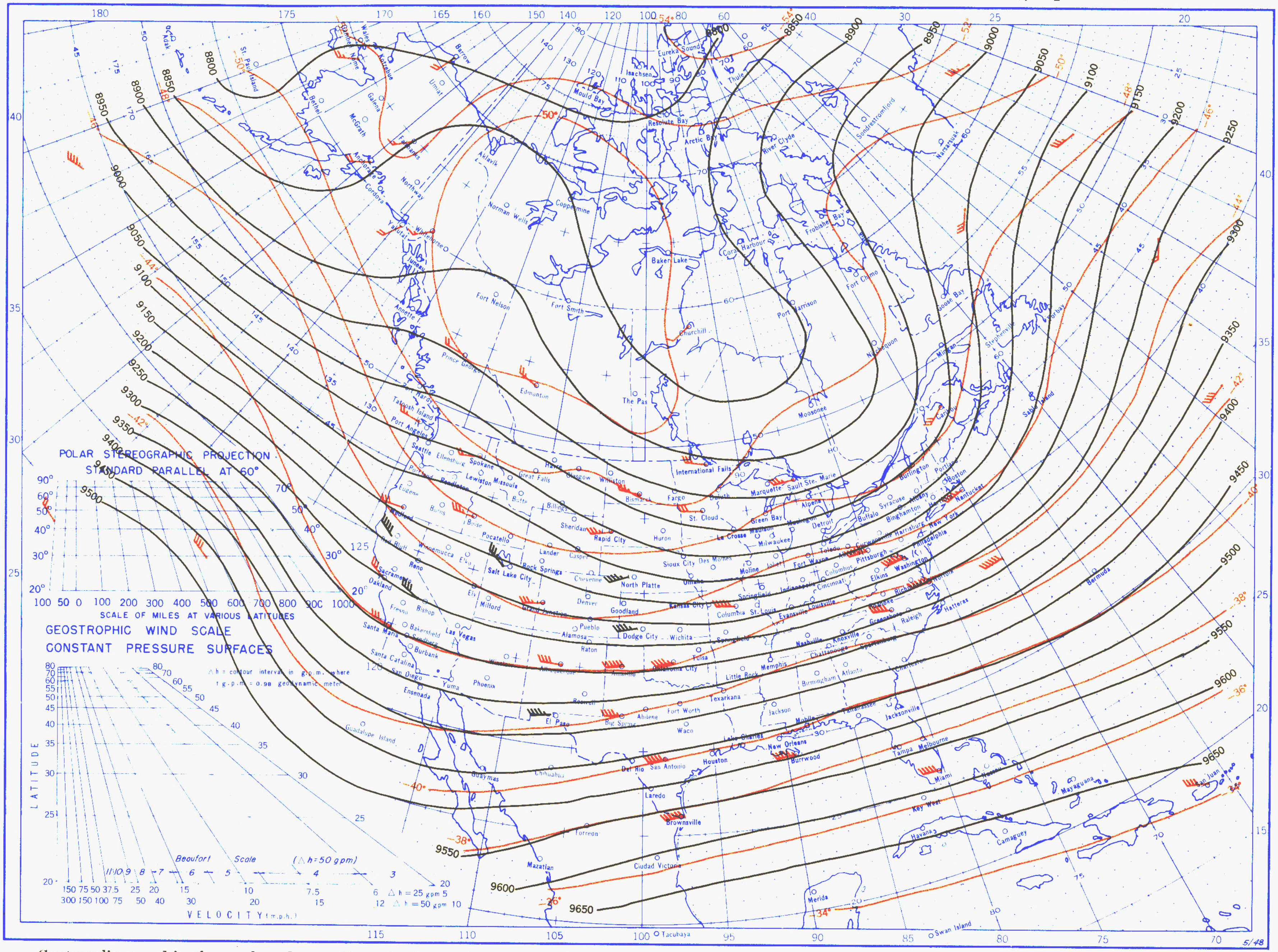
Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins taken at 0300 G. M. T.

Chart XIV. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 500-mb. Pressure Surface, Average Temperature in °C. at 500 mb., and Resultant Winds at 5000 Meters (m.s.l.), April 1953.



Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins at 0300 G. M. T.

Chart XV. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 300-mb. Pressure Surface, Average Temperature in °C. at 300 mb., and Resultant Winds at 10,000 Meters (m.s.l.), April 1953.



Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins at 0300 G. M. T.